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Stress sonography of the ulnar collateral ligament of the elbow in professional baseball pitchers: a 10-year study.

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Stress Sonography of the Ulnar Collateral Ligament of the Elbow in Professional Baseball Pitchers: A 10 Year Experience

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Abstract

Background: Injury to the ulnar collateral ligament (UCL) of the elbow is potentially career threatening for elite baseball pitchers. Stress ultrasound (SUS) of the elbow allows for evaluation of both the UCL and the ulnohumeral joint space at rest and with stress.

Hypothesis: Stress ultrasound can identify morphologic and functional UCL changes and may predict risk of UCL injury in elite pitchers.

Study design: Cross-sectional study; level of evidence III

Methods: Three hundred and sixty-eight asymptomatic professional baseball pitchers underwent preseason SUS of their dominant and non-dominant elbows over a 10-year period (2002–2012). Stress ultrasounds were performed in 30° of flexion at rest and with 150 Newton of valgus stress by a single musculoskeletal radiologist. Ligament thickness, ulnohumeral joint-space width, and ligament abnormalities (hypoechoic foci and calcifications) were documented. Players who subsequently incurred a UCL injury had prior SUS findings compared to the asymptomatic players.

Results: There were 736 SUS studies. Mean UCL thickness in the dominant elbow (6.15mm) was significantly greater than the non-dominant elbow (4.82 mm; $P < 0.0001$). The dominant-elbow stressed ulnohumeral joint-space width (4.56mm) was statistically greater than the non-dominant elbow (3.72 mm; $P < 0.02$). In the dominant arm, hypoechoic foci and calcifications were both statistically more prevalent (28% vs. 3.5% and 24.9% vs. 1.6%, respectively; $P < 0.001$). In the 12 players that incurred a UCL injury, there were non-significant increases in baseline ligament thickness, ulnohumeral joint-space gapping with stress, and incidence of hypoechoic foci and calcifications. One hundred and thirty-one players had more than one SUS with an average increase of .78 mm in joint-space gapping with subsequent evaluations.

Conclusion: Stress ultrasound indicates that the UCL in the dominant elbow of elite pitchers is thicker, more likely to have hypoechoic foci and/or calcifications, and has increased laxity with valgus stress over time. Players with a UCL injury may have increased baseline SUS abnormalities in their dominant elbow compared to asymptomatic players.

Keywords: baseball; stress elbow ultrasound; ulnar collateral ligament

What is known about the subject: UCL injuries of the elbow in professional baseball pitchers can be debilitating and, in certain cases, career-ending. Stress elbow ultrasound is a safe, fast, and noninvasive imaging modality that has been used to demonstrate structural and functional abnormalities of the UCL.

What this study adds to existing knowledge: Stress elbow ultrasound has the ability to detect anatomic changes to the UCL in asymptomatic, professional baseball pitchers. These changes progress over time and persist with continued exposure to pitching at an elite level. Currently, it is not known for certain if these changes are adaptive or detrimental, but with continued longitudinal surveillance, it may be possible that stress elbow ultrasound can identify asymptomatic pitchers at risk for future UCL injury.

Introduction

Overhand athletes exert tremendous forces through the medial elbow joint during the act of throwing. The ulnar collateral ligament (UCL) of the elbow, more specifically its anterior band, is the primary soft-tissue stabilizer to the valgus stress of throwing in these athletes (5,29). Over time, the extreme repetitive stress of throwing, especially in the elite baseball pitcher, may lead to either acute injury or chronic, progressive damage to the elbow and, more precisely, to this ligament. Current diagnosis of injury to the UCL relies on history and physical examination as well as radiographic imaging, which often assists in confirming the diagnosis of UCL injury. Typically, imaging workup of the elbow includes plain radiography, stress radiography, and magnetic resonance imaging (MRI) with or without enhancement (2,7, 9, 31, 34). Plain radiography may precisely define bony changes such as osteophytes, cystic changes, joint-space narrowing, or loose bodies (2,31, 34), but it does not provide any direct information on soft-tissue injury. In addition, it is a static test with the elbow in one position for each view obtained. Stress radiography has been proposed as a more precise, functional way of evaluating UCL laxity (15, 26,35), but it also does not provide direct assessment of the ligament, may be cumbersome to use, and may be provider dependent (32). Conventional MRI provides excellent visualization of acute ruptures of the UCL (4,19) but may be less precise for partial-thickness injury (12, 23, 37). Magnetic resonance arthrography (MRA) has been proposed as a more accurate technique for partial or chronic UCL injury (12, 23, 37), but MRA has several limitations, including expense, length of study time, and invasiveness (12, 23, 32, 37). Quite often, elite level pitchers are extremely reluctant to have contrast injected into their injured, dominant elbow. In addition, MRA is a static imaging technique; though it may clearly identify irregularities in the UCL, it does not provide any dynamic assessment of ligament laxity because the player's elbow is in one position throughout the procedure.

Stress ultrasound (SUS) is a unique imaging technique that directly visualizes the UCL and allows assessment of ligament laxity as related to joint-space gapping with stress (24, 29, 32, 36) (Figure 1A,B). The ability of this technique to precisely visualize the UCL of the elbow with a cadaveric evaluation has been previously determined (32) . Additionally, the early results of this technique in major league baseball pitchers have identified it as a low-cost, quick, and noninvasive imaging modality for the UCL (32). Moreover, it allows an evaluation of UCL laxity by applying stress, either manually or instrumented, to assess the amount of joint space gapping as compared to the contralateral elbow (32,36).

Injury to the UCL of elite baseball pitchers may occur either acutely or with chronic repetitive stress (7, 9, 11). In chronic, progressive injuries, there may be a point when structural changes in the UCL of the dominant elbow are not yet symptomatic but detectable by SUS. Preliminary data has identified such changes as hypoechoic foci, calcifications, and joint gapping in asymptomatic elite pitchers (32). The purpose of this current study was to identify morphologic changes on SUS in a large study population of pitchers and determine if these changes progress with continued exposure to pitching at an elite level. In addition, we aimed to compare the SUS changes noted in those elite pitchers who subsequently incurred a clinically symptomatic UCL injury with the SUS findings of the remaining, asymptomatic pitchers. Most importantly, our goal was to determine if SUS may provide a predictive risk of UCL injury in elite level baseball pitchers as related to a particular level of morphologic and dynamic abnormalities identified by this imaging technique.

Material & Methods

Study Population

A total of 736 SUS studies were performed on the elbows of 368 professional baseball pitchers during minor league spring training over a 10-year period (March 2002 to March 2012). The mean age of the pitchers was 22.8 years (range, 17–34 years). All pitchers were members of the same professional baseball team and were evaluated with SUS during their spring training pre-participation examination. The subjects had an average professional baseball experience of 2.5 years (range, 0–14 years). There were 278 (76%) right-handed pitchers and 90 (24%) left-handed pitchers. All pitchers were asymptomatic at the time of their studies. The SUS studies were all obtained at the request of the head team physician as a baseline scan for comparison if any of the pitchers were to subsequently incur a UCL injury during the season. Institutional review board approval had been obtained, and all subjects provided written informed consent.

Imaging Technique

All subjects were imaged by the same experienced sonologist with a multifrequency 13-MHz linear-array transducer (SonoSite MicroMaxx or M-Turbo; SonoSite, Bothell, WA) and standard acoustic coupling gel. Subjects were seated, and their right elbow was placed at 30° (as measured with a digital goniometer and the longitudinal axes of the forearm and upper arm) in a standardized instrumented device (Telos, Marburg, Germany). This elbow flexion angle was selected for two reasons: 1) the UCL has been demonstrated to be the primary restraint against valgus stress at 30° of elbow flexion and, 2) appropriate application of stress using the standardized stress device can only be consistently applied at lower degrees of elbow flexion (the players' elbows could not be appropriately positioned in the stress device at flexion angles greater than 60 degrees). The thickness of the anterior band of the UCL at its midportion and the width of the ulnohumeral joint space at the level of the anterior band were measured both at rest and with 150 Newtons of stress applied (Figure 2A-D). All images were evaluated for echotextural abnormalities, including hypoechoic foci and calcifications (Figure 3). The calcifications were defined as hyperechoic foci that demonstrated acoustic shadowing (32). All electronic caliper measurements (thickness at rest and stress, joint space at rest and stress) and gray-scale echotextural findings were transcribed to a computer spreadsheet (Excel; Microsoft, Redmond, WA) for later analysis. These measurements were taken once by the sonologist on the ultrasound screen utilizing electronic calipers with a precision of 0.1 mm. The same measurements were obtained for the left elbow in the same sequence. All the SUS studies were videotaped on the ultrasound monitor, and still-frame images of the measurements were recorded on optical disks. During the SUS studies and the image interpretation, the sonologist was blinded to each pitcher's arm dominance.

Statistical Analysis

A retrospective cohort study was performed using prospectively collected data, assessing all players with more than one SUS scan during the study period with respect to all evaluated parameters. Players who subsequently incurred a UCL injury had their prior SUS scan findings compared to the remaining asymptomatic group of pitchers. Univariate statistical analysis with independent sample *t* test was used for all continuous variables. Continuous variables included 1) ligament thickness with and without stress in dominant and non-dominant elbows, 2) ulnohumeral joint space with and without stress in dominant and non-dominant elbows, 3) correlation of gray-scale abnormalities with years in professional baseball, 4) ligament thickness and joint space data between the subsequently injured subgroup and the asymptomatic subgroup. Categorical variables including hypoechoic foci and calcifications in dominant and non-dominant elbows were analyzed with chi-squared statistic and Fisher exact test. Correlated analysis was performed comparing initial versus final SUS findings of the dominant elbows in all pitchers with more than one ultrasound. Finally, we conducted a Spearman Rank correlation coefficient analysis to examine the relationship between ligament thickness and joint space width with stress. In determining whether or not potential predictors could be obtained with respect to injury, a post-hoc power analysis was performed. Results were considered statistically significant if the P value was < 0.05. Independent sample t-test was used, and STATA (v. 11.0) statistical software (StataCorp, College Station, TX) was used to perform all the analysis.

Results

UCL Thickness

Data on thickness of the anterior band of the UCL for all pitchers are listed in Table 1. At rest, the mean thickness of the UCL was 6.15 mm in the dominant elbows and 4.82 mm in the non-dominant elbow. This difference was statistically significant (P=<0.001).

Ulnohumeral Joint Space

Data on joint space width for all pitchers are listed in Table 2. The joint space width at rest was 3.32 mm in the dominant elbow and 2.94 mm in the non-dominant elbow. This was not statistically significant. When stress was applied, however, the joint space width of the dominant elbow was statistically greater (P < 0.003) than the non-dominant elbow, with values of 4.56 mm and 3.72 mm, respectively. The average change in joint space width, defined as the width of the ulnohumeral joint space with stress minus that at rest, was 1.24 mm in the dominant elbow and .78 mm in the non-dominant elbow. The difference between dominant and non-dominant elbows was statistically significant (P = 0.004). Using Spearman Rank correlation analysis, we noted a positive, although weak, correlation between ligament thickness and joint space width stressed.

Echotextural Abnormalities

The prevalences of hypoechoic foci and calcifications in the anterior band of the UCL of all pitchers are listed in Table 3. Hypoechoic foci were detected in 103 (28%) of the dominant elbows and 13 (3.5%) of the non-dominant elbows of all 368 pitchers. Calcifications were noted in 92 (24.9%) of the dominant elbows and 6 (1.6%) of the nondominant elbows of all 368 pitchers. The prevalences of both hypoechoic foci and calcifications were statistically greater in the dominant elbow compared to the nondominant elbow ($P < 0.001$ for both).

Longitudinal Changes and UCL Injury

During the study period, 131 pitchers (36%) had more than one SUS scan (Table 4). Thirty-five of the 131 (26%) were noted to have an average increase of 0.78 mm joint-space gapping (increase in ulnohumeral joint space) with stress on subsequent SUS studies. There was no significant progression noted on subsequent SUS studies with respect to hypoechoic foci or calcifications. Twelve of the 368 pitchers (3.3%) incurred an injury to the UCL during the study period. These pitchers had a specific event resulting in symptoms, physical findings, and MRA documenting partial or complete anterior band UCL damage. The baseline SUS studies of these 12 pitchers, prior to their injury, were compared to the remaining, asymptomatic 356 pitchers with respect to all data parameters. The comparison data for the injured and asymptomatic subgroups are listed in Table 5.

We observed increased ligament thickness (6.84 mm vs. 6.11 mm), joint-space gapping with stress (4.5 mm vs. 4.09 mm), and proportion of players with hypoechoic foci (42% vs. 29.4%) and calcifications (25% vs. 24%) in the 12 injured players compared to the asymptomatic 356 players. However, given the small number of UCL injured players during the study period, we were unable to find any significant relationship between the presence of these changes and subsequent UCL tearing. Of the 131 pitchers with more than one SUS scan during the study period, nine subsequently incurred a UCL injury. There was no significant difference in progression of joint-space gapping, hypoechoic foci, or calcifications between those nine players with UCL injury and the other 119 players who remained asymptomatic.

Discussion

This study supports the hypothesis that SUS can identify morphologic changes of the UCL in elite pitchers as well as evaluate the ulnohumeral joint-space width at rest and with stress. At the present time, SUS is unable to allow a determination of relative risk of future UCL injury in this population.

Overhand athletes exert tremendous forces through the medial elbow joint during the act of throwing. UCL injuries were first recognized and described by Waris in a series of 17 javelin throwers in 1946 (35). More recently, UCL injuries have gained increasing attention in the medical and lay press in regards to their effect on elite baseball pitchers. Once thought to be a career-ending injury for these athletes, a novel surgical technique, developed by Jobe in 1974, allows for successful return to competition (22). Despite improvements in training and conditioning, diagnostic methods, and surgical treatment, the incidence of injuries among pitchers has been slowly increasing in recent years (11). Pitchers with UCL injuries, in particular, are often placed on the "disabled list," which requires them to rest from competition for a minimum of 15 days. More importantly, if surgical treatment is required it may take as long as 12–18 months to return to previous level of competition (3,6,14, 20).

Injuries to the anterior band of the UCL may occur either acutely or chronically (7,9,11). In either situation, injuries are often diagnosed by history, physical examination, and radiographic imaging, and if they are near complete or complete, most require surgical reconstruction in the elite level pitcher. Although imaging tests are often used to help corroborate the findings on history and physical examination, chronic injuries may have a more insidious onset and may be a diagnostic challenge. Asymptomatic, elite-level throwers may have baseline progressive, adaptive changes in the UCL on imaging studies that may not correlate with the future risk of injury (24, 25). Wright et al used plain radiographs to examine a cohort of 56 asymptomatic professional baseball pitchers and found that degenerative changes developed over time, but these changes did not correlate to time spent on the Major League Baseball disabled list or risk of future injury (41). In addition, it is difficult for plain radiographs to accurately assess the structural integrity of the UCL or detect any associated soft-tissue injury. Conventional MRI provides excellent visualization of complete tears of the UCL, heterotopic calcification, flexor-pronator inflammation, and associated bony edema (19, 23, 31,34, 37). The addition of contrast to conventional MR imaging has increased detection of partial and subtle chronic injuries to the UCL; however, expense, length of time, invasiveness, and patient reluctance has made its routine use in elite-level pitchers less desirable (12, 23, 32, 37). Magnetic resonance imaging, with or without arthrography, also does not provide any functional or dynamic assessment of the ligament.

The UCL of the elbow, specifically its anterior band, is the primary soft-tissue stabilizer to the valgus stress with throwing (5,30). An imaging modality that can accurately evaluate the UCL in a stressed position may provide more useful information than one that evaluates the UCL in a fixed, extended position as is the case with plain radiography and MRI. Rijke et al have used a calibrated device to produce a valgus stress during radiography to evaluate patients with UCL injuries (35). Lee et al used radiography to compare the amount of ulnohumeral joint-space gapping with and without stress in “normal” individuals. They found a significant difference in the amount of gapping when 5 lbs of valgus stress was applied at 0° and 30° elbow flexion. There was no difference, however, in gapping whether they looked at the non-dominant or dominant elbow (26). Ellenbecker et al performed a similar study, but looked specifically at uninjured, professional baseball pitchers. They found a significantly greater difference in the amount of ulnohumeral joint-space widening with stress when comparing the dominant to non-dominant elbows. They concluded that increased medial elbow laxity exists in the dominant arms of uninjured pitchers (15). Despite providing a functional assessment of the ulnohumeral joint space, these reports utilizing plain radiography cannot simultaneously comment on the structural properties of the UCL or surrounding soft-tissue structures, which are also functionally important factors.

Elbow ultrasound is a useful imaging modality to detect injuries of the bony and soft-tissue structures of the elbow, including tendons, ligaments, muscles, bursae, and neurovascular structures. It is also safe, rapid, non-invasive, non-radiating, and inexpensive for therapeutic, guided injections and can be used in patients with claustrophobia or positioning difficulties (27, 28, 38). Furthermore, it has been shown to be effective in detecting both partial- and full-thickness tears of the UCL, echotextural abnormalities (hypoechoic foci and calcifications), and ulnohumeral osteophytes (13, 24, 29, 32, 39). The contralateral extremity is readily accessible for comparison, and, most importantly, a stress device can be used to provide a measured dynamic and functional assessment of the UCL (13, 36, 39). Wood et al (40) (1 patient) and DeSmet et al (13) (2 patients) reported cases of collegiate-level baseball pitchers who sustained UCL injuries diagnosed on SUS. In all cases, they were able to demonstrate medial valgus instability with appropriate stress, and images of the contralateral elbow were obtained for comparison. They were able to accurately detect UCL injury in all cases that were later confirmed at the time of surgical reconstruction. Sasaki et al performed SUS on 30 asymptomatic, collegiate baseball players (36). They showed that the ulnohumeral joint space of the dominant elbow was significantly wider than that of the non-dominant elbow and that increased laxity occurred with valgus stress. Their SUS methods were slightly different than the current study as they placed the elbow in 90° flexion, used gravity stress instead of manual stress, and did not comment on the actual qualitative characteristics of the UCL. In addition, only 12 of the players in their cohort were pitchers. In a previously published study, SUS was performed on 26 asymptomatic, professional pitchers. The results of this study showed that the anterior band of the UCL was thicker, more likely to have echotextural abnormalities, and had increased laxity with valgus stress in the dominant elbow of these pitchers (32).

The valgus stress applied to all elbows during this study was standardized by utilizing the Telos stress device. This allowed a consistent force to be applied, thereby eliminating a potential source of variation. Studies suggest that during the late cocking/acceleration phases of throwing, when the UCL is subjected to the highest valgus stress, the elbow is at 60-90° of flexion (1, 8, 7, 9) Theoretically, testing the elbow at 60-90 degrees of flexion with the Telos device would most closely approximate the clinical setting. The proper use of this device, however, requires that the elbow be placed within a narrow, low range of elbow flexion so that the fixation pads contact the players forearm and upper arm. This assures that the exact amount of stress is applied to the medial elbow. This required positioning, however, did not allow the players' elbows to be placed at 60-90 degrees of flexion. And so, because of the variation in elbow flexion in the late cocking/acceleration phases of throwing, the limitations of proper Telos use, and previous biomechanical studies that have identified the UCL as the primary restraint against valgus stress at 30° of elbow flexion, this elbow flexion angle was subsequently chosen for all testing (30).

In the current study, we noted baseline anatomic changes of the UCL in the dominant elbows of elite-level baseball pitchers. We found that the mean thickness of the UCL was significantly greater in the dominant compared to the non-dominant elbow. We also found that the gapping of the stressed ulnohumeral joint space was significantly greater in the dominant elbow. Echotextural abnormalities were more likely to be present in the dominant elbows of the pitchers as well. These changes in UCL thickness, joint space gapping with stress, and echotextural abnormalities may be adaptive and secondary to repetitive throwing. The current study is unable to determine if their presence may or may not predispose pitchers to subsequent UCL injury. Despite this, these findings serve as a baseline for medical caretakers of these players for comparison if subsequent UCL injury does occur. In addition, SUS may also be beneficial for medical caretakers in scenarios where surgical treatment is being contemplated, such as for those pitchers found to have partial tearing on MRI arthrogram, those with medial elbow pain who have had previous UCL reconstruction, and those who are having difficulty despite adequate non-operative treatment.

Hopefully, with further data collection and continued longitudinal surveillance, whether or not these findings correlate with risk of future UCL injury may possibly be determined.

The strengths of this study include the size of the study group and the length of the study period. It represents the largest and longest clinical study on the use of SUS for the evaluation of the UCL in professional baseball pitchers. In addition, the current study extended over a 10-year time period, and we were able to obtain multiple years of SUS studies for more than one third of our athletes. It provides both quantitative assessment of the UCL with a standardized stress device and qualitative assessment of UCL ultrastructural changes with throwing. Furthermore, all ultrasound data collected over the entire 10 year study period was obtained by the same experienced musculoskeletal ultrasonographer.

There were a few limitations in this study. There was no independent control group of non-overhand throwing athletes. However, we were able to use the non-dominant elbow as a suitable control. Secondly, there were a relatively small number of throwers with injured UCLs during the study period that could be used as a subgroup comparison to non-injured throwers. Only 12 pitchers required a UCL reconstruction during the 10-year study period. This low number of UCL reconstructions, although good for the baseball organization, did not allow any statistical significance to be achieved during this study period. An increased number of players requiring UCL reconstruction would have made these observed results statistically significant (post-hoc analysis revealed that with a sample size of 17 subjects, the findings would have approached statistical significance.) We will continue to collect data to amass larger numbers of UCL injuries in efforts to identify possible risk factors, such as increased ligament thickness, change in ulnohumeral joint space with stress, and presence of echotextural abnormalities. Thirdly, only 131 (36%) of the pitchers remained with the team long enough to have more than one SUS during the study period. This, however, is unavoidable when studying professional baseball pitchers as the nature of the sport often dictates that players change teams frequently. Moreover, we did not have any pitching history data pertaining to skill level, position in the rotation and pitch counts. Several reports have shown that these factors play a role in the incidence of elbow pain, elbow injury, and need for elbow surgery in youth and adolescent pitchers. It is possible that these unknown factors may have had an effect on our results. (16-18, 33) Lastly, since our data was obtained from asymptomatic individuals, it is difficult to say with certainty if these observed abnormalities on SUS correlate with clinical symptoms and instability. Despite this, our study has shown that SUS can be used for long-term surveillance of the elbows of elite level pitchers.

Summary

We have shown that SUS can detect anatomical changes to the UCL in asymptomatic, professional baseball pitchers. These abnormalities progress over an extended period of time and persist with continued exposure to pitching at an elite level. We were unable to determine if these abnormalities are directly associated with risk of future UCL injury due to a low number of UCL reconstructions performed over the 10-year study period. With continued longitudinal surveillance, we hope to precisely define risk factors on SUS for future UCL injury in this athletic population.

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Figure Legends

Figure 1. Bilateral ultrasound images of the ulnar collateral ligament (UCL) in an asymptomatic professional baseball pitcher. A) Image of the nonpitching arm shows a normal UCL (arrow). B) Image of the pitching arm shows a slightly thicker UCL that contains a hypoechoic focus (arrow). E, medial epicondyle; T, trochlea; C, coronoid process.

Figure 2. Clinical and ultrasound images at rest and with valgus stress in the pitching arm of an asymptomatic professional baseball pitcher. A) Photograph demonstrating stress ultrasound of elbow in Telos device. B) Photograph demonstrating valgus stress being applied to elbow by Telos device. C) At rest, the ulnohumeral joint (asterisks) measures 4.2 mm. D) With valgus stress applied by the Telos device, the ulnohumeral joint (asterisks) widens to 7.9 mm. T, trochlea; C, coronoid process.

Figure 3. Ultrasound images of the pitching arm of an asymptomatic professional baseball pitcher. Calcifications (arrowheads) are seen within a thickened, hypoechoic ligament. E, medial epicondyle; T, trochlea; C, coronoid process.

Table 1. Thickness in millimeters of the anterior band of the UCL in the dominant and nondominant elbows of all pitchers at rest.

Thickness	**Dominant**	**Non-Dominant**	**P value**
At Rest	6.15 +/- 1.57 mm	4.82 + / - 1.32 mm	<.001

Table 2. Joint space width in millimeters of the anterior band of the UCL in dominant and non-dominant elbows of all pitchers at rest, with Telos stress, and the difference.

Joint Space	**Dominant**	**Non-Dominant**	**P value**
At Rest	3.32 +/- .07 mm	2.94 +/- .12 mm	.61
With Stress	4.56 +/- 1.10 mm	3.72 +/- .92 mm	<.003
Difference (stress – rest)	1.24 +/- 1.04 mm	.78 +/- .65 mm	<.004

Table 3. The prevalences of hypoechoic foci and calcifications in the anterior band of the UCL in the dominant and non-dominant elbows of all pitchers.

	Dominant N (%)	**Non-Dominant N (%)**	***P* value**	**X^2(DF)**
Hypoechoic	103 (28)	13 (3.5)	<.001	10.7(2)
Calcifications	92 (24.9)	6 (1.6)	<.001	7.1(1)

X^2 = Chi-square; DF = degree of freedom

Table 4. Change over time between initial and final SUS characteristics of 131 pitchers who had at least 2 yearly ultrasounds.

	Initial Mean (SD)	Final Mean (SD)	*P* value	
Thickness (at rest)	6.05 +/- 1.44 mm	6.12 +/- 1.60 mm	.62	
Joint space (at rest)	3.08 +/- .74 mm	2.96 +/- .73 mm	.11	
Joint space (stressed)	4.00 +/- 1.12 mm	4.37 +/- .99 mm	.001	
Change in joint space (stressed-rest)	1.17 +/- .96 mm	1.03 +/- .72 mm	.06	
	N(%)	**N(%)**	***P* value**	**X^2(DF)**
Hypoechoic foci	65 (49)	70 (53.4)	.65	8.37(1)
Calcifications	40 (30.5)	35 (26.7)	.24	24.9(1)

X^2 = Chi-square; DF = degree of freedom

Table 5. Comparison of baseline SUS studies of the anterior band of the UCL in the dominant elbows of pitchers with subsequent UCL injury and those pitchers remaining asymptomatic.

	Injured (n = 12)	**Asymptomatic (n = 340)**	***P* value**	
	Mean (SD)	**Mean (SD)**		
Thickness (at rest)	6.84 +/- 1.56 mm	6.11 +/- 1.57 mm	.19	
Joint space (at rest)	3.44 +/- 1.34 mm	3.08 +/- 1.77 mm	.44	
Joint space (stressed)	4.55 +/- 1.52 mm	4.09 +/- 1.25 mm	.44	
Change in joint space (stressed-rest)	1.06 +/- .88 mm	1.12 +/- .95 mm	.83	
	N(%)	**N(%)**	***P* value**	**X^2(DF)**
Hypoechoic foci	5(42)	100(29.4)	.17	1.90(1)
Calcifications	3(25)	81(24)	.68	.17(1)

X^2 = Chi-square; DF = degree of freedom